

What is claimed is:

- 1 1. A thermosyphon for enhancing cooling of electronic systems, the
2 thermosyphon receiving heat from a heat-dissipating component and com-
3 prising:
4 a central evaporator in contact with the heat-dissipating com-
5 ponent;
6 a condenser in fluid communication with and extending around
7 the periphery of the evaporator;
8 a liquid coolant partially filling the condenser and at least par-
9 tially filling the evaporator; and
10 means for cooling the condenser.
- 1 2. A thermosyphon as recited in claim 1, wherein the cooling means
2 comprises cooling fins.
- 1 3. A thermosyphon as recited in claim 2, wherein the cooling fins ex-
2 tend from the condenser.
- 1 4. A thermosyphon as recited in claim 1, wherein the cooling means
2 comprises a fluid-cooled jacket adjacent to the condenser, the jacket defining
3 a volume holding fluid that is cooler than the liquid coolant in the condenser,
4 the fluid flowing through the jacket.
- 1 5. A thermosyphon as recited in claim 4, wherein the fluid-cooled
2 jacket extends around the periphery of the condenser.
- 1 6. A thermosyphon as recited in claim 1, further comprising means for
2 evacuating the thermosyphon.

1 7. A thermosyphon as recited in claim 1, further comprising a boiling
2 enhancement structure disposed within the evaporator.

1 8. A thermosyphon as recited in claim 7, wherein the boiling en-
2 hancement structure comprises a plate having a first major surface and a
3 second major surface, both surfaces having parallel grooves cut in them, the
4 grooves in the first surface being perpendicular to the grooves in the second
5 surface.

1 9. A thermosyphon as recited in claim 8, wherein the grooves in each
2 surface are cut to a depth that is at least one half of the thickness of the
3 boiling enhancement structure plate.

1 10. A thermosyphon as recited in claim 8, wherein the boiling en-
2 hancement structure material is selected from the group consisting of copper,
3 diamond, and silicon.

1 11. A thermosyphon as recited in claim 7, wherein the boiling en-
2 hancement structure comprises open-celled porous foam.

1 12. A thermosyphon as recited in claim 1, wherein the central evapo-
2 rator comprises:

3 a first plate having an interior major surface and an exterior
4 major surface;

5 a second plate, generally parallel to, spaced from, and similar
6 in planar dimension to the first plate, having an interior major surface
7 and an exterior major surface, the interior major surface opposing the
8 interior major surface of the first plate, with a central parallel plane

9 passing through the space therebetween, the second plate exterior
10 major surface in contact with at least a portion of the component and
11 extending outside the limits of that portion of the component, wherein
12 the interior major surfaces define an evaporator volume.

1 13. A thermosyphon as recited in claim 12, wherein the second plate
2 further includes an opening that places the heat-dissipating component in di-
3 rect contact with the liquid coolant, and the second plate sealingly engages
4 the component.

1 14. A thermosyphon as recited in claim 12, wherein the second plate
2 is formed with at least a portion of the heat-dissipating component from a
3 single piece of material.

1 15. A thermosyphon as recited in claim 12, wherein the cooling
2 means comprises a peripheral cooling plate extending from the condenser in
3 a plane generally parallel to the central plane.

1 16. A thermosyphon as recited in claim 15, further comprising cooling
2 fins extending from the peripheral cooling plate in a direction away from the
3 central plane.

1 17. A thermosyphon as recited in claim 12, wherein when the central
2 plane is horizontal and the first plate is above the second plate, the liquid
3 coolant fills the evaporator.

1 18. A thermosyphon as recited in claim 12, wherein through the
2 range of angular orientation from when the central plane is horizontal and the

3 first plate is above the second plate, to when the central plane is vertical, the
4 evaporator is substantially full of liquid coolant.

1 19. A thermosyphon as recited in claim 12, wherein through the range
2 of angular orientation from when the central plane is horizontal and the first
3 plate is above the second plate, to when the central plane is vertical, the
4 evaporator is full of liquid coolant.

1 20. A thermosyphon as recited in claim 12, wherein at all orientations
2 the evaporator is substantially full of liquid coolant.

1 21. A thermosyphon as recited in claim 20, wherein when the central
2 plane is horizontal, the liquid coolant fills the evaporator both when the first
3 plate is above the second plate and when the second plate is above the first
4 plate.

1 22. A thermosyphon as recited in claim 12, wherein at all orientations
2 the evaporator is full of liquid coolant.

1 23. A thermosyphon as recited in claim 12, wherein the condenser
2 comprises:

3 a first wall extending from each evaporator plate, the first wall
4 having an interior surface, a proximate edge and a distal edge, the
5 proximate edge sealingly joined to the periphery of the respective
6 plate, and the first wall extending perpendicularly from the entire pe-
7 riphery of each plate in a direction away from the central plane for a
8 substantially constant distance, whereby the distal edge is substan-
9 tially parallel to the plates;

10 a second wall extending from each respective first wall, each
 11 second wall having an interior surface, a proximate edge and a distal
 12 edge, the proximate edge of each second wall sealingly joined to and
 13 extending perpendicularly from the entire distal edge of the adjoining
 14 first wall in a direction away from the evaporator volume; and
 15 a third wall extending from each respective second wall, each
 16 third wall having an interior surface, a proximate edge and a distal
 17 edge, the proximate edge of each third wall sealingly joined to and
 18 extending perpendicularly from the entire distal edge of the adjoining
 19 second wall such that the distal edges of the respective third walls
 20 abut and sealingly join at the central plane, whereby the interior sur-
 21 faces of the first, second, and third walls define a condenser volume in
 22 fluid communication with the evaporator volume.

1 24. A thermosyphon as recited in claim 20, wherein each plate and its
 2 respective walls are formed from a unitary piece of material.

1 25. A thermosyphon as recited in claim 23, wherein at all orientations
 2 the evaporator is substantially full of liquid coolant.

1 26. A thermosyphon as recited in claim 25, wherein the planar shapes
 2 of the evaporator and condenser peripheries are substantially rectangular.

1 27. A thermosyphon as recited in claim 26, wherein the cross-
 2 sectional shape of the condenser along an edge of the evaporator and per-
 3 pendicular to the central plane is generally rectangular, the condenser is
 4 generally symmetric about the central plane, and the dimensions of the
 5 evaporator and condenser approximately satisfy the following relationship,
 6 where H_B is the height of the condenser, H_E is the distance between the inte-

rior surface of the second plate and the interior surface of the first plate, L_B is the distance that the condenser extends from the periphery of the evaporator, perpendicular to the respective edge of the evaporator, L_E is the length of the evaporator along one edge, and W_E is the length of the evaporator along an edge perpendicular to the edge having length L_E :

$$H_B/H_E = (2L_B + L_E + W_E)/L_E.$$

28. A thermosyphon as recited in claim 27, wherein when the central plane is horizontal, the surface of the liquid coolant is approximately a distance of $(H_B + H_E)/2$ from the interior surface of the plate that is beneath the coolant.

29. A thermosyphon as recited in claim 25, wherein the planar shapes of the evaporator and condenser peripheries are substantially square.

30. A thermosyphon as recited in claim 29, wherein the cross-sectional shape of the condenser along an edge of the evaporator and perpendicular to the central plane is generally rectangular, the condenser is generally symmetric about the central plane, and the dimensions of the evaporator and condenser approximately satisfy the following relationship, where H_B is the height of the condenser, H_E is the distance between the interior surface of the second plate and the interior surface of the first plate, L_B is the distance that the condenser extends from the periphery of the evaporator, perpendicular to the respective edge of the evaporator, and L_E is the length of the evaporator along each edge:

$$H_B/H_E = 2(1 + L_B/L_E).$$

31. A thermosyphon as recited in claim 30, wherein when the central plane is horizontal, within the condenser limits the surface of the liquid cool-

3 ant is approximately a distance of $(H_B + H_E)/2$ from the interior surface of the
4 plate that is beneath the coolant.

1 32. A thermosyphon as recited in claim 23, wherein at all orientations
2 the evaporator is full of liquid coolant.

1 33. A thermosyphon as recited in claim 32, wherein the planar shapes
2 of the evaporator and condenser peripheries are substantially circular.

1 34. A thermosyphon as recited in claim 33, wherein the cross-
2 sectional shape of the condenser along the condenser radius and perpen-
3 dicular to the central plane is generally rectangular, the condenser is gener-
4 ally symmetric about the central plane, and the dimensions of the evaporator
5 and condenser approximately satisfy the following relationships, where H_B is
6 the height of the condenser, H_E is the distance between the interior surface
7 of the second plate and the interior surface of the first plate, R_B is the radius
8 of the condenser as measured from the center of the evaporator to the outer
9 limit of the condenser, and R_E is the radius of the evaporator, and when the
10 central plane is vertical, ϕ is the angle away from vertical of a line formed by
11 the condenser radius when the outer endpoint of the condenser radius inter-
12 sects the surface of the liquid coolant that fills the evaporator:

$$\phi = \frac{\pi}{2} \left(1 - \left(\frac{R_E}{R_B} \right)^2 \right) \left(1 - \frac{H_E}{H_B} \right) + \frac{R_E}{R_B} \sqrt{1 - \left(\frac{R_E}{R_B} \right)^2}$$

$$\phi = \cos^{-1} \left(\frac{R_E}{R_B} \right)$$

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36. A thermosyphon as recited in claim 32, wherein the planar shapes
of the evaporator and condenser peripheries are substantially square.

$$14 \quad \theta^* = \tan^{-1} \left(\frac{L_B}{L_R + L_F} \right);$$
$$16 \quad \frac{H_B}{H_E} = \frac{2 \left(1 + \frac{L_B}{L_E} \right) \frac{L_B}{L_E}}{\frac{L_B}{L_E} + \left(\frac{1}{2} + \frac{L_B}{L_E} \right) \tan \theta}; \text{ and}$$

18 for $\theta^* \leq \theta \leq 45^\circ$:
 19

$$20 \quad \frac{H_B}{H_E} = \frac{1 + \frac{L_B}{L_E}}{1 + \frac{1}{2} \left\{ 1 - \frac{1}{2} (\tan \theta + \cot \theta) \right\} \frac{L_B}{L_E}}.$$

1 38. A thermosyphon as recited in claim 37, wherein when the central
 2 plane is horizontal, within the condenser limits the surface of the liquid cool-
 3 ant is approximately a distance of $(H_B + H_E)/2$ from the interior surface of the
 4 plate that is beneath the coolant.

1 39. A thermosyphon for enhancing cooling of electronic systems, the
 2 thermosyphon receiving heat from a heat-dissipating component and com-
 3 prising:

4 a central evaporator in contact with the heat-dissipating com-
 5 ponent;

6 a condenser in fluid communication with and extending around
 7 the periphery of the evaporator;

8 a liquid coolant partially filling the condenser and substantially
 9 filling the evaporator at all thermosyphon orientations; and

10 means for cooling the condenser,

11 wherein thermosyphon performance is substantially independent of thermo-
 12 syphon orientation.

1 40. A thermosyphon as recited in claim 39, wherein the thermosy-
 2 phon is generally planar and has a central plane passing therethrough, and
 3 the liquid coolant fills the evaporator at any orientation where the central
 4 plane is horizontal.

1 41. A cooling-enhanced electronic component comprising:
 2 a heat-dissipating electronic element;
 3 a casing in which the element is disposed;
 4 a thermosyphon adjacent to the casing, the thermosyphon
 5 comprising:
 6 a central evaporator in contact with the heat-dissipating
 7 component;
 8 a condenser in fluid communication with and extending
 9 around the periphery of the evaporator;
 10 a liquid coolant partially filling the condenser and sub-
 11 stantially filling the evaporator at all thermosyphon orientations;
 12 means for cooling the condenser; and
 13 wherein thermosyphon performance is substantially independent of thermo-
 14 syphon orientation.

1 42. A cooling-enhanced electronic component as recited in claim 41,
 2 wherein the thermosyphon is generally planar and has a central plane pass-
 3 ing therethrough, and the liquid coolant fills the evaporator at any orientation
 4 where the central plane is horizontal.

1 43. A method of cooling a heat-dissipating electronic element, which
 2 comprises the steps of:
 3 providing a thermosyphon, comprising:
 4 a central evaporator;
 5 a condenser in fluid communication with and extending
 6 around the periphery of the evaporator;
 7 a liquid coolant partially filling the condenser and at least
 8 partially filling the evaporator; and
 9 means for cooling the condenser; and

10 placing the evaporator in contact with the heat-dissipating ele-
11 ment.

1 44. The method of claim 43, further comprising the step of providing a
2 void in the evaporator to allow the coolant to directly contact the heat-
3 dissipating element.